

Draft
Wiswall Dam Aquatic Ecosystem Restoration Project
Incremental Analysis

The following incremental analysis was conducted in order to quantify the habitat benefits associated with providing fish passage in the Lamprey River beyond Wiswall Dam and the various alternatives for accomplishing this. The historical habitat before the dam construction was a natural free-flowing river, with its associated anadromous and riverine fish populations. However, the construction of the dam, by creating an artificial impoundment, has changed this habitat from riverine to lacustrine resulting in the loss of the historic anadromous fish runs and riverine fish community; replacing them with a warmwater fish assemblage. In addition, several acres of wetland have been created that are supported by the existing water level of the impoundment. These wetlands provide habitat for a variety of aquatic, avian, and terrestrial wildlife. In addition, the impoundment created by the dam is utilized as a secondary water supply for the town of Durham, New Hampshire. Therefore, in order to determine the most effective way of restoring the aquatic habitat (which currently eliminates the upstream migration of anadromous fish), it is necessary to quantify the habitat benefits that will be incurred with each alternative. These alternatives are; 1) No Action; 2) Dam Removal; 3) Construction of a Denil Fish Ladder, and 4) construction of a nature-like bypass channel around the dam. Although each of these alternatives will accomplish the objective of fish passage (with the exception of No Action), they will have different effects upon the overall habitat of the impoundment upstream from the dam. The effects of these alternatives upon the habitat will be discussed below.

Existing Habitat

Three major ecosystem components will be evaluated in order to characterize and quantify the relative value of the habitats upstream from the dam, which are expected to change in response to each of the alternatives. These are 1) lacustrine habitat, maintained by the existing impoundment, which supports a characteristic fishery; 2) riverine habitat, which currently exists upstream of the impoundment and downstream from the dam and would increase under various alternatives supporting a characteristic riverine and/or anadromous fish population; and 3) wetland habitat, which occurs upstream from the dam adjacent to the main lake on each side of it, connected to it by side channels.

Historical Fisheries

1. Anadromous/Riverine Fisheries

The Lamprey River historically supported runs of anadromous river herring (alewives and blueback herring), shad, sea lamprey, and Atlantic salmon, as well as the catadromous American eel. With the construction of the first dams on the Lamprey,

including the Wiswall Dam in Durham, these fish were no longer able to access their upstream spawning areas (or rearing areas for catadromous species), and consequently, those populations were eliminated and/or densities reduced from the areas upstream from each of these dams. In addition, the creation of an impoundment upstream from the dam has changed the habitat from riverine to lacustrine, with the resulting changes in the resident fish population from coldwater to warmwater.

The fish assemblage in the Wiswall Dam impoundment includes largemouth bass, smallmouth bass, yellow perch, bluegill sunfish, brown bullhead and chain pickerel. In addition trout are stocked both upstream and downstream of the dam. Although natural reproduction of trout species occurs both up and downstream from Wiswall Dam, it has not been reported in the area of the impoundment. Historic riverine fish species along the two mile corridor of the Lamprey River immediately upstream (based on existing fisheries data collected upstream) included blacknose and longnose dace, creek chub, darters, white sucker, as well as brook trout (see Environmental Assessment for complete list of species). Currently, an anadromous river herring run exists below Wiswall Dam, with returning fish passing through the fish ladder at Macallen Dam in Newmarket. Atlantic salmon have also been stocked below the Wiswall Dam in Newmarket, with the turning adults successfully passing through the fish ladder at the Macallen Dam on their way upstream. However, the Wiswall Dam has prevented these anadromous species from passing further upstream on the Lamprey River. The provision of fish passage beyond the Wiswall Dam will allow these anadromous fish access to an additional 43 miles of riverine habitat, opening up a previously blocked migratory corridor with its associated spawning habitat. In addition, some of the resident species (i.e. brown and brook trout, as well as smallmouth bass) have been observed passing through the fish ladder at the Macallen Dam in Newmarket, and would be expected to pass beyond the Wiswall Dam as well if fish passage were provided.

2. Lacustrine/Warmwater Fisheries

As noted above, the construction of the dam has resulted in the creation of approximately two miles of lacustrine habitat upstream from the dam, which supports the fish assemblage listed in the Environmental Assessment. The impoundment was sampled in August 2003 and revealed a healthy warmwater fish community. . Direct observation of the area indicates large areas of backwater, shallow vegetated inlets, with forested canopy adjacent and connected to the main impoundment apparently functioning as spawning, nursery and forage habitat for many warmwater fish species. During a site visit in early December of 2001, several small bass species appearing to be in the age class of either 1+ or 2+ were directly observed in a channel located on the left bank of the river (looking downstream) approximately 0.75 miles upstream from the dam, and active zooplankton were observed in a shallow forested inlet on the right side of the river. These extensive inlets and shallows are primarily maintained by the water level of the impoundment, and would drain if the dam were to be removed.

In 1994, an experimental drawdown of the Wiswall Dam impoundment was conducted in order to determine the effects of possible dam removal or accidental breach. The draw-down occurred over a 7 hour period, and resulted in water level drops ranging from 54 inches at the dam itself, to greater than 11 inches at Jenkins Lane, approximately 1.3 miles upstream from the dam near the upstream limits of the impoundment (Lamprey River Advisory Committee Report to the Town of Durham, 1994). It was noted that after two hours of draining, the marsh immediately upstream from the pumping station (i.e. Thompsons Marsh) was “*fully exposed and draining*” and “*Wetlands connected to the river in the vicinity of the pumping station and Thompson marsh were drained and discontinuous from the river. A variety of animals, including small fish, crayfish, sunfish, river herring, and bullhead, were stranded*”. Therefore, it is apparent that significant aquatic habitat exists upstream from Wiswall Dam maintained by the water level of the impoundment.

Wetland Habitat

Approximately 9.5 acres of wetlands are located upstream from Wiswall Dam on both sides of the river and are connected to the impoundment by shallow inlets. These wetlands include forested, scrub shrub, emergent and aquatic bed cover types, and are supported primarily by the water level in the impoundment. Extensive areas of scrub shrub occur on the northern shore, while areas of forested emergent mixed with small areas of aquatic bed wetland exists on the southern shore. In addition, areas of cattail marsh are located on the northern shore near the pumping station and the inlet. These became exposed during the experimental drawdown in 1994 noted above. The diversity of cover types associated with these wetlands provide habitat for a variety of wildlife species including nesting habitat for waterfowl (Wiswall Dam fish Passage Project Fact Sheet). The continuity of these wetlands with the larger impoundment allows waterfowl to nest in the backwater areas, while using the shallower open water associated with the wetlands for feeding (dabbling) and the deeper open water of the impoundment for resting and refuge. If the water level in the impoundment were to drop, these wetlands would drain and most likely revert to riparian forest.

Avian species that have been observed within the wetland and riparian areas of the Lamprey River Corridor include the pied-billed grebe, sedge wren, as well black duck and possibly the least bittern (based upon a vocalization) (Lamprey River Resource Assessment, 1994). All of these species can be associated with vegetated wetland areas containing cattail marsh, and while they may not have been specifically observed in the immediate vicinity of Wiswall Dam, could potentially occupy these wetlands given the habitat type(s) that occur there. In a similar emergent wetland in Milford Massachusetts, the least bittern as well as the pied billed Grebe have been observed, as well as mallard duck, which is generally associated and utilizes the same habitat types as black duck (Veit and Petersen, 1993, and Laughlin and Kibbe, 1985). Generally, these species all utilize extensive cattail and sedge emergent marshlands adjacent to open water. Nests are built in the dense vegetative stands, and for some species (i.e. pied billed grebe), in areas on stands surrounded by and/or above areas of open water. Food items consist of wetland

vegetation (i.e. seeds and/or plants) as well as aquatic invertebrates. It should be noted that the habitat requirements for all of these waterfowl, (as well as the other avian species noted above) depend upon the presence of open water (for foraging/dabbling) as well as the emergent wetland (for cover, and/or nesting). It will therefore be assumed, for this study that since similar habitat exists in the wetlands associated with the Wiswall dam impoundment, that these species can exist there.

Incremental Model

1. Application

In order to compare the habitat benefits gained from providing fish passage beyond the Wiswall Dam, it is necessary to compare the approximate habitat value of the Lamprey River with the Wiswall Dam in place and the associated impoundment, without fish passage (No Action Alternative) to the habitat value of the river with fish passage (with a project alternative). Providing fish passage is expected to improve the overall ecosystem restoring, it to a more historical condition by the reintroduction of anadromous fish and in the alternative of Dam Removal, the restoration of historic riverine habitat. However, in some of the alternatives, the amount of emergent and or aquatic bed wetlands may be reduced and/or eliminated, with resulting negative effects to some of the wetland/waterfowl habitat, as well as a reduction/elimination of the existing lacustrine habitat and associated warmwater fishery. In order to measure the benefits of the various restoration alternatives to the various habitat types, an evaluation of the quality and quantity of habitat suitable for various species (both aquatic and wetland) is necessary. The model presented below will be used to measure the overall changes in habitat that may occur incrementally with each of the various fish passage alternatives. This includes effects on wetlands (measured by waterfowl habitat), lacustrine habitat (measured by its ability to sustain target lacustrine fish species), and riverine habitat, measured by its ability to sustain target anadromous fish species.

2. Model Design

a. Description

The U.S. Fish and Wildlife Service has developed Habitat Suitability Index Models for its Habitat Evaluation Procedures Methodology (HEP), which measure the suitability of a given habitat for one or more species. These models use habitat criteria (variables) that are necessary to support various species (and their life stages) in a given habitat. These habitat criteria (variables) are generally measurable in a given area of habitat, and range in value from 0 (unsuitable) to 1 (optimal). By measuring each of these variables, summing and/or obtaining a geometric or arithmetic/weighted mean for them, an overall value of the habitat (i.e. Habitat Suitability Index or HSI) can be obtained for a given species in a given habitat. When comparing various alternatives, the individual habitat variables can be estimated as to their expected change under each of

the alternatives. The final HSI obtained for each variable for a given species can then be multiplied by the acres of the restoration project to obtain another value, Habitat Units, which are a measure of the overall quality of the habitat (for that species) in the project area that will result from the restoration.

When evaluating an entire ecosystem, generally a group of species is selected which represent the various habitat types. The total Habitat Units calculated for each species are summed for each alternative and compared to determine which alternative provides the most effective restoration (based upon total habitat units gained by the project). When determining the habitat units for several species, it is possible for some of the same variables (which are essential to all species) to be measured and incorporated more than once (i.e. once for each target species). Therefore, a model, which can evaluate certain required habitat criteria common to more than one species, may be preferable to one that evaluates each individual species, and could provide a more general and/or alternative way of evaluating the overall quality and/or quantity of a habitat for a certain function.

The Habitat Suitability Index Models (noted earlier), published by the U.S. Fish and Wildlife Service, contain habitat suitability criteria necessary for all life stages of these species for a specific habitat. As noted earlier, many of the essential water quality (as well as physical habitat) criteria are common to several of the various freshwater lacustrine fish species as well riverine species. These include necessary water quality criteria (i.e. pH, turbidity, temperature, dissolved oxygen) and physical/morphological habitat components (i.e. forage, benthic invertebrates). By grouping specific life requisite criteria common to several target species into a single habitat component, a basic life requisite index for any body of water can be obtained. This can then be applied (by using a geometric mean) toward additional species-specific criteria necessary for a target species. For other non-fish species, a group of common wetland criteria can be developed as well, and then multiplied by target wetland species criteria (as well as the lacustrine and riverine components) output in the same manner.

For example, most warm water/lacustrine habitats in New England support a warm water fish assemblage, which includes species such as bluegill and pumpkinseed sunfish, yellow perch, brown bullhead, chain pickerel, black crappie, and largemouth bass. Generally, since these fish are typically found in lacustrine habitats, they have similar habitat requirements, which are common to more than one individual species. All of them (with the possible exception of brown bullhead) have similar dissolved oxygen requirements. Therefore, by measuring the range of dissolved oxygen levels in a specific habitat, the suitability of that habitat for a number of species that generally use this habitat and share similar dissolved oxygen requirements can be determined. Additional basic habitat requisites (such as forage habitat, pH, turbidity) that are common to a group of species can be measured, and then used as a general basic habitat model for a given type of habitat which supports a range of species. Species-specific habitat requirements can then be added, based upon target species, and weighted according to that species importance the ecosystem. The entire group of basic as well as species specific habitat requisites can then be either summed or multiplied (either to obtain a weighted and/or

geometric mean) to obtain an overall habitat index which will rate the quality of the habitat to support a variety of species common to the area, as well as individual target species. The same approach can be applied to other ecosystem components in a given project, or other habitat types (such as wetlands as well as riverine) to obtain a total value ranging between 0 and 1, for each of them. The model presented below utilizes this method in order to obtain a measure of the habitat quality the Lamprey River Corridor and the impoundment behind Wiswall Dam under various restoration alternatives.

3. Methods for Habitat Evaluation Model Used for Wiswall Dam

The differences between the model used below and the existing Habitat Suitability Index Models published by the Fish and Wildlife Service primarily have to do with the generalization and combination of several basic life requisites common to more than one species for the given habitat, with the addition of species specific criteria, to obtain a single overall suitability index for a given habitat type (or cover type); as opposed to using multiple species models and obtaining a suitability index for each species. However, the model below relies upon the Habitat Suitability Index Models to determine the general life requisite variables as well as the species variables. Other literature is also used, as well as professional judgment. Also, where many of the Habitat Suitability Index Models generally incorporate a geometric mean to reflect the necessity of each of the individual variables, or life requisites (and to express their independence), the model presented below uses both a geometric mean and weighted (arithmetic) mean to obtain the habitat index value (for each habitat type). This allows the essential life requisites to have the greatest effect on the overall output, in that if any one of them has an individual suitability index value of 0, the suitability index value of that entire habitat component becomes 0 regardless of any non-0 values of the other requisites (i.e. the habitat model is “life requisite” limited). However, if not all of the species specific criteria are suitable, and the general life requisites are suitable, then the total value of the habitat will still be above 0 (as long as there is at least one species specific criterion that is above 0), indicating that the habitat will support aquatic life at least temporarily, even though some of the requirements for a particular target species may be absent

For the model below a geometric mean is used for the essential life requisites necessary for more than one species in a given habitat type, and the result is then multiplied by a weighted mean of the species specific variables for the target species for that habitat type. This causes the habitat suitability index (for that habitat type) to become 0 if any one of the essential life requisites (for that type) is not met regardless if all of the species-specific habitat criteria are met (for that habitat type). Since there is more than one habitat type being evaluated for the Lamprey River in the vicinity of the Wiswall Dam, each of the habitat types can be evaluated in the same way, in order obtain individual habitat suitability indices (HI) for each habitat type. The number of acres of the proposed project, or the number of acres of that particular habitat type in the project area that will be affected by each of the alternatives can then be multiplied by the HI for that particular habitat type.

As noted above, the three habitat types which will be evaluated for the Lamprey River upstream from Wiswall Dam include Riverine; which includes the acres of the Lamprey River upstream from the limits of the impoundment and associated tributaries which would become accessible to anadromous fish if fish passage beyond Wiswall Dam was provided; Lacustrine, which includes the area of the impoundment created by the dam, as well as some of the shallow inlets adjacent to the main river which are maintained by the dam spillway elevation; and Wetland, which includes the fringing wetlands adjacent to the impoundment on both sides of the Lamprey River upstream from the dam, which are also maintained primarily by dam spillway elevation. The habitat indices (HI) calculated for each of these types can be multiplied by the total project area, or the total area (acres) of that particular habitat type within the proposed project area, that will become available with each of the alternatives, in order to obtain the total habitat units for that habitat type (i.e. riverine, wetland or lacustrine, etc.). The general formula is as follows:

$$\{[(GRf) * (TRf)]^{1/2}\} = HI(f);$$

$$\{[(GRr)*(TRr)]^{1/2}\} = HI(r); \text{ and,}$$

$$\{[(GRw)*(TRw)]^{1/2}\} = HI(w)$$

where

GRf = The geometric mean of each of the general lacustrine fisheries habitat requisites

TRf = The sum of the species specific habitat requisites (weighted mean) for specific lacustrine fish

GRr = The geometric mean of each of the general riverine/anadromous fisheries habitat requisites

TRr = The sum of the species specific habitat requisites (weighted mean) for specific riverine/anadromous fish

GRw = The geometric mean of each of the general wetland habitat requisites

TRw = The sum of each of the species specific habitat requisites (weighted mean) for specific wetland species i.e. waterfowl

HI(n) = Habitat Suitability Index for either riverine, lacustrine, or wetland habitat, ranging between 0 and 1.

The individual components are further defined as follows:

$$GRf = \{\prod_{i=1}^n grf_i\}^{1/n}$$

where

grf = each of the individual *general* essential habitat life requisites for lacustrine fish; and

$$TRf = \{\sum_{i=1}^N trf_i\}$$

where

trf = each of the *specific habitat requisites* for target lacustrine fish species (weighted according importance), and

$$\mathbf{GRr} = \{\prod_{i=1}^n \mathbf{grr}_i\}^{1/n}$$

where

grr = each of the individual *general* essential habitat life requisites for selected riverine species

and,

$$\mathbf{TRr} = \{\sum_{i=1}^N \mathbf{trr}_i\}$$

where

trr = each of the *specific* habitat requisites for target riverine/anadromous species (weighted according importance), and;

$$\mathbf{GRw} = \{\prod_{i=1}^n \mathbf{grw}_i\}^{1/n}$$

where

grw = each of the individual *general* essential habitat life requisites for selected wetland species

and,

$$\mathbf{TRw} = \{\sum_{i=1}^N \mathbf{trw}_i\}$$

where

trw = each of the *specific* habitat requisites for target wetland species (weighted according importance).

Habitat Units are then obtained by the formula $\mathbf{HI}(n) * \mathbf{A}(n) = \mathbf{HU}(n)$, where

HI= Habitat Index obtained for either the lacustrine, riverine or wetland component from the above formulae

(n)= The Specific habitat type (i.e. lacustrine, riverine or wetland/waterfowl)

A = Area of specific habitat type available for each proposed alternative within the project area

HU(n) = Habitat Units for the specific habitat type

The total habitat Units available for each habitat component for each alternative can then be summed according to the formula:

$$\mathbf{HU}(\mathbf{Total}) = \{\sum_{i=1}^N \mathbf{HU}_i\}$$

Where

HU (Total) = the total Habitat Units from all habitat types

The application of the above formulae to the Lamprey River project in the vicinity of Wiswall Dam will be discussed below.

Application of Generic Model to Wiswall Dam

In this incremental analysis, the overall habitat quality of the Lamprey River ecosystem upstream from the Wiswall Dam (i.e. the impoundment and associated wetlands) will be evaluated under each of the proposed alternatives in order to determine the most effective restoration plan (i.e. the one which maximizes all of the various habitat benefits for lacustrine, riverine and wetlands). Comparison is made between the existing (lacustrine) fish habitat which has been formed by the construction of the dam and blocks the migration of anadromous fish, the wetlands habitat created by the impoundment, and provides habitat for a variety of wildlife species, and the proposed restored migratory corridor (with or without the dam) which will allow the upstream (and downstream) passage of anadromous fish. In addition, the effects to the associated fringing wetlands habitat will be examined since this may be affected by the proposed alternatives.

Fisheries Habitat

1. Lacustrine Habitat/Species

Since there is a warmwater fishery which exists in the impoundment behind the Wiswall Dam, benefits and/or effects of the various fish passage alternatives on this fish population will be specifically examined. As noted previously, the existing impoundment supports fringing wetlands connected by inlets, containing shallow water (utilized as spawning and nursery habitat for many warmwater species) as well as deeper water habitat, which can be used for adult cover and over wintering (i.e. depths of the impoundment at 3000 feet upstream from the dam is approximately 15 feet). The target species selected for this comparison is largemouth bass, since it currently exists in the impoundment and the habitat appears to be physically suitable for it based upon the observable features of the impoundment. In addition, since these fish currently are present in the impoundment, it can be assumed that the basic habitat requirements for them are being met. In addition, it is assumed that the habitat requisites for this species will change in response to the various alternatives.

As noted in the previous section, in order to measure the changes in these requisites, a geometric mean was calculated by assigning individual values to each of a series of habitat components, which are necessary to generally support fish, and a weighted mean calculated to a series of habitat components essential to support target fish species (i.e. as noted for the lacustrine habitat component of Wiswall Dam, the target species is largemouth bass). These components (including the target species) were selected according to their importance in supporting fish and/or their function in the ecosystem (expected and existing). These were combined according to the general formula noted earlier. The HI calculated for each component was multiplied by the acres of that habitat type for each alternative to obtain the habitat units. These were totaled to calculate the total habitat units (for each type of habitat) for each of the alternatives.

Methods

Fisheries/Aquatic Habitat Component

General habitat criteria that are necessary to support lacustrine as well as riverine fish species that presently (and historically, since the construction of the dam) occupied the Wiswall Dam impoundment were selected (GRf and GRr). These include the basic requisites for fisheries and/or aquatic life, which will change in response to dam removal and/or reduction of the elevation of the holding pond, and for which data sets are available. In addition, specific habitat requisites for a target lacustrine and riverine fish species were selected (TRf and TRr), which are also expected to change in response to dam removal and/or construction of a fish ladder. These target requisites were considered partially-independently of the basic habitat requisites that are necessary to support any type of fishery, in that they apply to an individual species, but also depend on the basic habitat requisites being met. This target fish grouping can consist of one or more target species, weighted according to their importance in the ecosystem and/or habitat restoration priority. As noted however, if any of the general requisites is unsuitable (value of 0), then the specific habitat requisites (for the target fish species) also become 0, due to their being multiplied by the index value obtained for the general requisites (which is a geometric mean of each of the individual variables necessary to support both lacustrine fish). This was done for each of the ecosystem components being examined for the Wiswall Dam fish passage project (i.e. Lacustrine, Riverine, and Wetland/waterfowl). These requisites are listed below:

General Requisites for Lacustrine Fisheries Habitat (GRf)

1. Dissolved oxygen (grf₁)
2. Turbidity (grf₂)
3. Temperature (grf₃)
4. Benthic invertebrates (grf₄)
5. Cover (grf₅)
6. Forage (grf₆)

Species Specific Requisites for Warmwater Target Fish Species Habitat (TRf)

(Target Species for Wiswall Dam is largemouth bass. Each of these requisites will be evaluated for the habitat as to its effect for each of target fish species.)

1. Littoral Habitat (trf₁)
2. Spawning substrate (trf₂)
3. Deepwater Habitat (trf₃)

General Requisites for Riverine Fisheries Habitat (GRr)

1. Dissolved oxygen (grr_1)
2. Turbidity (grr_2)
3. Temperature (grr_3)
4. Benthic invertebrates (grr_4)
5. Cover (grr_5)
6. Forage (grr_6)
7. Flow (grr_7)

Species Specific Requisites for Riverine/Anadromous Target Fish Species Habitat (TRr)

(Target Species for the riverine habitat component of Wiswall Dam are Alewife, American shad, and Atlantic salmon). Each of the following requisites will be evaluated for each of the alternatives relative to its effect on the each target fish species.

1. Upstream passage (trr_1)
4. Downstream passage (trr_2)
5. Spawning Habitat (trr_3)

(Discussion of how these variables will change specific to the various Wiswall Dam fish passage alternatives will follow in the next section).

A value was assigned to each of the requisites within each of the two functional groups of each habitat type (i.e. lacustrine, riverine or wetland) ranging from 0 to 1 depending on its existing condition with the dam in place and no fish passage, and its expected change for each of the fish passage alternatives. A value of 0 is the poorest condition, and a value of 1 is optimal condition. The actual value for each requisite was determined by consideration of specific data obtained from the Lamprey River and comparing it to established criteria published in scientific literature as well as using direct observation of the affected habitat (using professional judgment). Many of the criteria that were used for both the general habitat requisites (GRf) and the specific habitat requisites (TRf) were found in the specific habitat suitability models for that species (HEP models).

These individual values assigned to each of the requisites were incorporated into the formula noted earlier for each of the habitat types to obtain the individual habitat indices (HI). These Habitat Indices (HI) were then multiplied by the total acreage of that particular habitat type in the project to obtain the Habitat Units (HU) for that specific habitat type for each of the proposed fish passage alternatives for the Lamprey River upstream from Wiswall Dam (Table 1). As noted earlier, these alternatives include 1) No Action; 2) Dam Removal; 3) Construction of a Fish Ladder, and 4) Construction of a Nature Like Stream Bypass Channel Around the Dam

Discussion of Values for Lacustrine Habitat

General Requisites (GRf)

Dissolved Oxygen (grf₁) – Dissolved oxygen is required for all aquatic life. Water quality criteria for many freshwater fish species require a level of at least 5 mg/L, below which they begin to show signs of stress. Data collected by the N.H. State DES from the Lamprey River from the Wiswall Road bridge, indicated mean dissolved oxygen levels (collected over a two year period) in the Wiswall Dam impoundment of 7.87 mg/L, which is above the 5 mg/L criterion established for supporting aquatic life, with the exception of August 7, 1999, when it was 4.81 mg/L. These dissolved oxygen levels indicate near optimal water quality to support various lacustrine fish species, with the exception of the one value in August that was slightly below 5 mg/L. During the summer, it has been reported that flow over the dam spillway is reduced to “a trickle” indicating that there is likely to be thermal and/or dissolved oxygen stratification behind the dam, as a result of the longer hydraulic residence times and natural biological oxygen demand which exists in the bottom substrate and/or water column. However, since sediment sampling has indicated minimal sediments occur behind the dam, it is assumed that sediment oxygen demand behind the dam is minimal.

Therefore, for the existing conditions this requisite was assigned a value of 0.75. With the Dam Removal Alternative, it was assigned a value of 1.0 since the free flowing river will maximize aeration of the water, maintaining saturation. For the Denil Fish Ladder and Nature-Like Bypass Channel Alternatives, the dam and impoundment will remain, therefore there will be little or no effect on the existing dissolved oxygen level in the impoundment, so for these two alternatives, this requisite was assigned a value of 0.75 for each.

Turbidity (grf₂)-Excessive turbidity in the form of suspended solids is detrimental to maintaining healthy aquatic life. Generally, excessive turbidity (resulting from high levels of suspended solids) can destroy benthic organisms preyed upon by many fish species at various life stages, by suffocation as well as covering over their sandier habitat. This can negatively affect the fisheries by eliminating the food supply of many fish larvae and adults. In addition, high levels of turbidity in the form of suspended solids can directly suffocate fish eggs and larvae, as well as irritate the gills of all life stages of most fish species. This can also lead to stress and/or suffocation. In addition, many fry and juvenile fish species feed primarily by sight, and elevated turbidities can significantly reduce visibility in the water column (El-Zarka 1959, from Krieger et al 1983). Largemouth bass are adversely affected by high levels of turbidity, which interfere with reproductive processes and reduce growth (Stuber et al, 1982). Black crappie prefer clear water and grow faster in areas of low turbidity (Edwards et al, 1982). Therefore, optimal lacustrine habitat would be that with low levels of turbidity.

As discussed in the Environmental Assessment, most of the Lamprey River in the vicinity of the Wiswall Dam impoundment, supports Class B Water Quality Standards,

for which the turbidity criterion states “Class B Waters shall not exceed naturally occurring conditions by more than 10 NTU’s...” (New Hampshire DES, Surface Water Quality Regulations, Chapter 1700, December 10, 1999). Therefore, it is assumed that turbidity levels of the Lamprey River in the vicinity of the Wiswall Dam impoundment are suitable for the survival and reproduction of resident lacustrine fish species. These levels are not expected to be significantly affected by any of the alternatives, and are therefore assigned a value of 1 for all of the project alternatives.

Temperature (grf₃)- The Wiswall Dam, has changed the historical riverine habitat of the Lamprey River to lacustrine habitat for an approximate distance of 1.5 miles upstream. The impounded water has a longer hydraulic residence time, which can increase the amount warming during the spring and summer months (particularly in the surface layers). Although this can be detrimental to coldwater fish species, it can be beneficial to many warmwater fish species such as largemouth bass (particularly young of year) by increasing growth/metabolic rates (assuming that food is not limiting). Therefore, this requisite was assigned a value of 0.75 for the No Action Alternative (not 1 since there is still some flow through the impoundment). For the Dam Removal Alternative this requisite was assigned a value of 0.50 (i.e. with respect to its affect on warmwater fish) since the free flowing water will not be subject to the warming that would occur in the impoundment. It was assigned a value of 0.75 for the Denil Fish Ladder Alternative, as well as the Nature-Like Bypass Channel Alternative, since the impoundment will remain in both of these alternatives.

Benthic Invertebrates (grf₄)- Benthic invertebrates constitute a major food component of many fish species during one or more life stages. Therefore, they are important even to top predators, since many of the fishes that they prey upon (forage species) in turn prey upon smaller benthic invertebrates. Many lacustrine fish species feed on benthic invertebrates during at least one stage of their life. Yellow perch juveniles will dwell on the bottom of the littoral areas of lakes, and feed on amphipods, ostracods, and chironomid larvae; and the prey items of larger yellow perch include aquatic insects (Ward and Robinson 1974; Kelso and Ward 1977, from Krieger et al, 1983). Also largemouth bass fry and juveniles include insects in their diets (Emig, 1966; Zweigacker and Summerfelt 1974; Carlander 1977; from Stuber et al, 1982), which can include mayfly nymphs, chironomid larvae, caddisfly nymphs, as well as dragonfly and damselfly nymphs depending upon the relative size of the fish that is feeding (Scott and Crossman, 1973).

Although benthic invertebrate samples were not collected from the Wiswall Dam impoundment, it appears that the shallow vegetated inlets adjacent to the river provide sufficient substrate for benthic fauna, which could be used as food items by resident warmwater fish, particularly juveniles. Observation of the substrate indicates that it is coarser sandy/mud, supporting rooted aquatic vegetation (as opposed to fine silt). Benthic organisms that can generally be found in sediments associated with slower moving waters (i.e. soft riverine substrata) include Tubicidae, Chironomidae, burrowing mayflies (Ephemiridae, Potamanthidae, Polymitarcidae), Prosobranchia, Unionidae, and and Spaheriidae. If there is vegetation present, then it can support additional species (Hynes,

1970). It is therefore assumed that these sediments can support a relatively diverse community of benthic fauna, particularly since they are vegetated. If the dam were removed, then these shallow inlets would be drained, and would no longer be useable nursery/forage areas for lacustrine fish. Therefore, this requisite was assigned a value of 0.75 for the No Action Alternative (assuming that the substrate is currently suitable to provide a relatively diverse population of benthic organisms). It is assigned a 0.5 for the Dam Removal Alternative, since these areas will be drained with other rockier areas exposed which would support those benthic species associated with swifter flowing water, less accessible and/or utilized by fry and juvenile lacustrine fish species. For the Denil Fish Ladder Alternative, it was assigned a value of 0.75 since the impoundment will remain, and for the Nature-Like Bypass Channel Alternative it was assigned a value of 0.80, since in addition to the maintenance of the existing water levels and shallow inlet habitat, invertebrate habitat will be created in the substrate of the artificial channel. There will also be the potential for benthic species to migrate from downstream of the dam to upstream via the substrate in the channel.

Cover (grf₅)– This is a necessary component for all types of fish habitat. Fish need cover (or structure) in order to hide/holdover during times of inactivity, and predator species will hide while waiting for prey. Smaller fish and/or juveniles need cover in order to hide from larger predators and feed, and spawning nests for largemouth bass and many other lacustrine fishes are built where there is cover. In addition, most areas of cover also provide substrate for aquatic invertebrates necessary as food items. In lacustrine systems, cover consisting of aquatic vegetation, submerged logs and/or other debris and rocks are used as nursery habitat for juvenile fish, where they can hide and feed.

As noted the extensive vegetated inlets adjacent to the impoundment provide areas of cover for both juvenile and adult warmwater fish species. These areas are currently maintained by the existing water level of the impoundment, and would drain, becoming unavailable if the dam were removed. Therefore, this requisite was assigned a value of 0.80 for the No Action Alternative; a value of 0.25 for the Dam Removal Alternative; a value of 0.80 for the Denil Fish Ladder Alternative (since the impoundment would remain); and a value of 0.800 for the Nature-Like Bypass Channel Alternative (since although the additional channel length and configuration could potentially provide additional cover for lacustrine fish, the area of habitat being evaluated is the impoundment behind the dam).

Forage (grf₆)- Larger predator fishes require forage species for food supply. Predator species in the Lamprey River include largemouth bass as well as chain pickerel. With the existing conditions, forage may include young of year bluegills and pumpkinseed, young of year yellow perch, white sucker, and golden shiner, as well as common shiner and fallfish, all of which have been found in the Lamprey River, and occupy specific locations in either the impoundment or slower flowing areas of the river. In lacustrine habitats, golden shiner can be a primary forage species. Generally this species prefers clear quiet, weedy areas with extensive shallow areas (Scott and Crossman 1973).

Given the habitat and information concerning the existing fishery, it is assumed that the existing forage base is sufficient to support the resident warmwater fish in the impoundment. Therefore this requisite was assigned a value of 0.50 for the No Action Alternative. For the Dam Removal Alternative it was assigned a value of 0.95 (relative to lacustrine habitat) since although most of the littoral areas of the impoundments utilized as nursery areas for forage species (i.e. golden shiner, bluegill, pumpkinseed) will be drained, with the influx of migratory fish into the system, forage will increase in the river to balance the reduction, therefore, the value was not lower. For the Denil Fish Ladder option this requisite was assigned a value of 0.85, since with fish passage, additional forage fish will be allowed access to the impoundment (i.e. white sucker, which have been observed in the fish ladder at the Macallen Dam in Newmarket, as well as the addition of up-migrating river herring through the impoundment), and the existing lacustrine habitat would not be drained. For the Nature Like bypass Alternative, this was assigned a value 0.85, since it is assumed that fish passage efficiency will be the same or higher than that of a fish ladder, effectively duplicating an open river, passing additional species and numbers of them. However, due to the uncertainties involved with this configuration, the value was kept the same as for the fish ladder option.

Discussion of Target Lacustrine Fish Species Habitat Requisites (TRf)

Largemouth Bass

As noted previously, the target warmwater fish species selected to represent the lacustrine habitat in the Wiswall Dam project area is largemouth bass. This species was selected rather than smallmouth bass since it is common to most lacustrine habitats in New England, it has been found in the Lamprey River in the vicinity of the Wiswall Dam impoundment, and it is generally found in a more lacustrine than riverine habitat than smallmouth bass. Therefore for modeling a lacustrine habitat component, it would appear to provide a better representation of the habitat. The three species-specific requisites that will be evaluated for this species are Littoral Habitat, Spawning Substrate, and Deepwater Habitat.

Littoral Habitat (trf₁)- Largemouth bass require littoral habitat (shallow areas) for spawning and nursery areas. Nests are constructed in water depths ranging from 0.15 meters to 7.5 meters, with the mean water depths ranging from 0.3- 0.9 meters (1-3 feet) (Stuber et al. 1982). Generally optimal largemouth bass habitat is characterized by lakes where at least 25% of the surface area of the lake and/or pond is shallow, i.e. less than 6 meters depth, and but deep enough (3-15 meters) for the fish to successfully overwinter.

The Wiswall Dam impoundment provides large areas of fringing wetlands and inlets, connected to the main channel, which would appear to provide sufficient littoral areas for largemouth bass spawning and nursery areas. As noted, the existing water level in the impoundment that supports these areas is maintained by the dam spillway elevation. If the dam is removed, these inlets would drain, and the habitat would revert to riverine, without these extensive inlets and shallow areas of vegetated open water.

Therefore, this requisite was assigned a value of 1 (optimal) for the No Action Alternative; and a value of 0.25 for the Dam Removal Alternative, since these shallow areas would drain. This requisite is assigned a value of 1 for both the Denil Fish Ladder and the Nature-Like Bypass Channel Alternatives, since the dam and impoundment will remain with the existing water levels for both of these alternatives.

Spawning Substrate (trf₂)-Optimal spawning substrate for largemouth bass is gravel, but other substrates, such as vegetation, roots, sand and mud are suitable. Silty and mucky bottoms are unsuitable (Numerous Citations, from Stuber et al, 1982). The Wiswall Dam impoundment with its shallow vegetated inlets and stable substrate appears to provide optimal spawning habitat for largemouth bass. Therefore this requisite was assigned a value of 1.0. For the Dam Removal Alternative, it was assigned a value of 0.25, since these areas will drain and leave rocky steep channel slopes (i.e. the historical river channel). For the Denil Fish Ladder and the Nature-Like Bypass Channel Alternatives, this requisite was assigned values of 1.0 for each, since the impoundment will remain with the existing shallow inlets.

Deepwater Habitat (trf₃)-Largemouth bass require depths of at least 9 feet to successfully over winter (from Stuber et al, 1982). Bathymetric survey data of the Wiswall Dam impoundment indicates depths ranging from approximately 12 feet behind the dam structure, to approximately 20 feet or greater in a large pool located approximately 0.5 mile upstream from the dam. These depths are sufficient for largemouth bass over wintering. Therefore, this requisite was assigned a value of 1 for the No Action Alternative, and 0.5 for the Dam Removal Alternative (since there will still be a deeper area of at least 10 feet at the deep pool noted above). It was assigned a value of 1.0 for both of the Denil Fish Ladder and the Nature-Like Bypass Channel Alternatives since the existing impounded water levels will remain.

Discussion of General Requisites for Riverine Fisheries Habitat (GRR)

Dissolved Oxygen (grr₁)- As noted above in the discussion on Lacustrine habitat, dissolved oxygen concentrations in the Wiswall Dam impoundment have generally met Class B Water Quality Standards, with mean levels of approximately 7.87 mg/l (collected over a two year period), with the exception of one record in August of 1997 when the dissolved oxygen concentration dropped to 4.81 mg/L. These levels are suitable for supporting most warmwater fish species. They are also suitable for supporting many salmonid species. However, at warmer water temperatures, (i.e. between 15° C and 19° C; what would be expected to occur in the Wiswall Dam impoundment during the summer), optimal dissolved oxygen requirements for these fish (i.e. brook trout data) are greater, ranging being above 9 mg/L (Raleigh, 1982). Therefore this requisite was assigned a value of 0.5 with the No Action Alternative and a value of 1.0 for the Dam Removal alternative (because aeration will be maximized in the free flowing river). For the Denil Fish Ladder and Nature-Like Bypass Channel Alternatives, it will be assigned a value of 0.5 (as in the No Action Alternative), since the impoundment will remain intact.

Turbidity (grr2) - as noted in the previous lacustrine discussion, turbidities meet Class B Water Quality Criteria. These values are not expected to be significantly changed for any of the project alternatives, so a value of 1 was assigned for each of them.

Temperature (grr3) As noted, water temperatures in the Wiswall Dam Impoundment can be influenced by the lowered hydraulic residence time resulting from the dam's impounded water. This can cause thermal stratification (during the summer months) with the upper levels of the warming and lower levels remaining cooler. While this may benefit warmwater fish, it does not benefit coldwater fish, restricting them to the lower sections of the water column. Dam removal would eliminate the impoundment replacing it with a flowing river, and minimize warming due to its longer exposure to solar radiation as would occur in an impoundment. Therefore this requisite was assigned a value of 0.5 for the No Action Alternative, a value of 0.75 for the Dam Removal Alternative (not 1.0, since the inflowing water is not always at optimal water temperature during the summer months). It was assigned a value of 0.5 for the Denil Fish Ladder Alternative (since the impoundment will remain). It is assigned a value of 0.65 for the Nature-Like Bypass Channel since it is expected that there will be some groundwater influence into the river in the channel location due to the fact that it will be excavated below the water table in some sections.

Benthic Invertebrates (grr4)- Based upon observation of the habitat and substrate in the fringing areas of the Wiswall Dam impoundment, it is presumed that there are suitable benthic invertebrates in the littoral areas of the impoundment to support most lacustrine species. No benthic invertebrate data has been collected in the lower levels of impoundment. However, sediment data indicates soft sediments are present along the margins, with the center of the channel generally scoured. These soft sediments can provide suitable substrate for a variety of benthic organisms provided that dissolved oxygen requirements are met. In addition even relatively scoured areas can provide habitat for organisms that can attach to rock and inhabit the interstices between them (also assuming that temperature and dissolved oxygen requirements are acceptable).

With the impoundment in place, specific water quality conditions favor those organisms that inhabit slower moving waters (i.e. noted above) rather than swifter currents. However, this does not preclude their consumption by salmonids and other riverine fish species that may reside in the impoundment. Therefore, this requisite was assigned a value of 0.75 for the No Action Alternative (the same as for the lacustrine habitat). It was assigned a value 1.0 for the Dam Removal Alternative, since this will generally increase flows and dissolved oxygen concentrations in the areas of the channel that were previously submerged with the impoundment in place, and make them available to resident fish species. For the Denil Fish Ladder, it was assigned a value 0.75 since the impoundment will remain, and for the Nature-Like Bypass Channel, it was assigned a value of 0.85 due to the additional coarse substrate that will be placed on the bottom of the channel which will serve as habitat and a migratory corridor for many benthic species (FAO, 2002).

Cover (grr5)- Although suitable littoral cover exists in the Wiswall Dam impoundment (as lacustrine habitat), minimal accessible cover exists in the actual channel itself since most of the rocky riverine substrate is submerged under several feet of water. During various times of the year, this may not be available to many fish due to the potential for dissolved oxygen depletion in the deeper layers of this artificial lake, due to the lower flows and increased Biological Oxygen Demand. In addition, these conditions may preclude the colonization of this existing cover by a more diverse invertebrate population. With the impoundment removed, these areas will become exposed, and form rock riffle runs and pools with increased flows and higher levels of dissolved oxygen, which could be better utilized by resident fish. Therefore this requisite was assigned a value of 0.25 for the No Action Alternative. It was assigned a value of 1.0 for the Dam Removal Alternative, since the historical riffle run sequence will be restored. For the Denil Fish Ladder Alternative it was assigned a value 0.80 since although the impoundment will remain, the Denil fish ladder itself will provide additional cover for upmigrating fish. For the Nature-Like Bypass Channel, it was assigned a value of 0.75 since the rock and riffle sequence of the channel will provide additional cover for riverine fish species. It was assigned a lower value than the Denil, due to the increased vulnerability of the fish in the channel as they pass through it.

Forage (grr6)-As noted in the lacustrine discussion, suitable habitat exists in the Wiswall Dam impoundment to support forage species for the larger predators that inhabit that section of the River. Generally, these forage fish would also be preyed upon by any larger riverine species (i.e. brook or brown or rainbow trout) inhabiting the impoundment. With the dam removed, much of the littoral habitat necessary for the production of these warmwater species would be removed, however the opening up of the historical riverine habitat (with its riffle/run/pool sequences) would allow population by stream dwelling fish species, such as blacknose and longnose dace, creek chub, fallfish, as well as up-migrating and down migrating river herring. These species can provide additional forage for salmonids as well as other riverine species (smallmouth bass). In Canadian streams young and adult blacknose dace serve as food for large brook trout (Scott and Crossman 1973). Therefore, this requisite was assigned a value of 0.50 for the No Action Alternative, and a value of 1.000 for the Dam Removal Alternative (since the habitat will be maximized for riverine species). For the Denil Fish Ladder Alternative it was assigned a value of 0.75 since the impoundment will remain and additional river herring may contribute to the forage base. For the Nature-Like Bypass Channel Alternative, it was assigned a value of 0.85, since the channel itself will provide additional habitat for small riverine species.

Flow Velocity (grr7)-Water flow velocity is necessary for determining species composition in a river. Generally salmonid species require flowing water (i.e. upwelling) for redd construction and egg incubation, and various stream dwelling aquatic invertebrate species lack gills, and depend upon their contact with flowing water for oxygen exchange. Increasing flow to an impoundment will provide better aeration and reduce warming and possible thermal stratification. It may also eliminate stagnant areas with lower dissolved oxygen levels. This will generally increase the suitability of the fish habitat. Therefore, a value of 0.25 is given for this requisite for the No Action

Alternative. For the Dam Removal Alternative a value of 1 is assigned for this requisite, since the flow will be restored to its historic condition. For the Denil Fish Ladder, it was given a value of 0.25 since the impoundment will remain. It was assigned a value of 0.50 for Nature-Like Bypass Channel option, due to the addition of the artificial flowing stream habitat.

Discussion of Target Riverine Fish Species Habitat Requisites (TRr)

As noted previously, the target fish species selected to represent the riverine habitat in the Wiswall Dam project area are alewife, American shad, and Atlantic salmon. The three species-specific requisites that will be evaluated for each of these species are upstream passage, downstream passage, and spawning habitat. Each of these fish species is assigned a value of 33.3% of the total riverine target fish species component (TRr).

Alewife

Upstream Passage (trr1)-With the existing conditions, there is no upstream passage for this species beyond the Wiswall Dam. Therefore this requisite was assigned a value of 0 for the No Action Alternative. With dam removal, there will be un-impeded fish passage from the Macallen Dam in Newmarket to the approximately 43 miles of riverine habitat upstream of Wiswall Dam. Therefore upstream passage will be optimized, and this requisite was assigned a value of 1.0 for the Dam Removal Alternative. For the Denil Fish Ladder Alternative this requisite was assigned a value 0.80, since Denil fish ladders are generally less than 100% efficient at passing target fish species (Laine, 2001; FAO, 2002; and Bunt et al, 1999). For the Nature-Like Bypass Channel Alternative this requisite was also assigned a value of 0.80. The bypass channel has the potential to more effectively pass all of the target fish species than a Denil fish ladder if the design criteria are met and it is designed to duplicate natural instream conditions. However, there is some uncertainty as to passage efficiency, due to a lack of comparable bypass channels in Eastern United States, so the index value of 0.80 reflects this uncertainty.

Downstream Passage (trr2)- Currently alewives are stocked in Pawtuckaway Lake, upstream from the Wiswall Dam in the Lamprey River watershed. The down-migrating juveniles (as well as post spawning adults) need to pass over the Wiswall Dam in order to enter the estuary. The lack of downstream passage requires that they pass over the spillway, which involves a 12-foot drop into shallow water with a rocky bottom, increasing the potential for injury. In addition, the low water flows, which occur at the spillway during the summer months, can further interfere with downstream migration over the dam. Therefore, this requisite was assigned a value of 0.25 for the No Action Alternative. With the Dam Removal Alternative, the restored river channel will optimize downstream passage so this requisite was assigned a value of 1 for this alternative. For the Denil Fish Ladder Alternative, there are plans to notch the spillway in order to improve downstream passage over the dam. However, the down-migrating fish will still

be required to drop into the shallow tail-water with a rocky bottom, which would increase their potential for injury. Therefore this requisite was assigned a value of 0.65 for this alternative. For the Nature-Like Bypass Channel Alternative, the fish will be able to follow the current and migrate through the channel without dropping over the spillway. Furthermore, during low flow periods, most of the water from the Lamprey River is designed to flow through the channel, and not over the spillway, so down migrating fish would have to use the channel. Therefore, this requisite is assigned a value of 0.90 (not a 1.0 since it is unknown how the down-migrating fish will utilize the channel during extremely low flows).

Spawning Habitat (trr3)-Alewives generally spawn in quieter waters and backwaters of flowing rivers, as well as upstream lakes. As a result of the stocking program, they currently spawn in Pawtuckaway Lake upstream from Wiswall Dam. In addition there is an indication of possible spawning in the Wiswall Dam impoundment, since they were found stranded in the upstream wetland during the experimental drawdown in 1994. There are approximately 43 additional river miles upstream from The Wiswall Dam where potential spawning habitat exists for this species, however exactly how much is actually optimal has not been determined (Doug Grout, personal communication, 2001). Although this area is currently inaccessible to alewives, it still exists and could be used as spawning area if these fish were transported over the dam and released. Therefore, this requisite was assigned a value of 0.75 for the No Action Alternative (since not all of the accessible area upstream may be suitable spawning habitat). For the Dam Removal Alternative, it was assigned a value of 0.70 since there may be some loss of spawning area due to the draining of the impoundment. For the fish ladder and Nature-Like Bypass Channel Alternatives it was assigned a value of 0.75 (for each) since the impoundment will remain in place, and the amount of upstream habitat will also be unchanged.

American Shad

Currently, there is no stocking program for this species upstream from Wiswall Dam. However, it is targeted for restoration, and will require fish passage beyond the dam in order for it to become established. Therefore it will be used in this incremental analysis of the project alternatives.

Upstream Passage (trr4)- As noted for alewife, with the dam in place, there is no upstream passage for this species beyond Wiswall Dam. Therefore this requisite was assigned a value of 0 for the No Action Alternative. For the Dam Removal Alternative, as with alewives, these fish will have un-impeded access beyond the dam to upstream spawning habitat. Therefore it was assigned a value of 1.0 for this alternative. For the Denil Fish Ladder Alternative, it was assigned a value of 0.80 due to the less than 100% efficiency of fish ladders. Also, upstream migration of American shad is not well understood, and therefore it is more difficult to design effective fish passage facilities for this species (Richard Quinn, U.S. Fish and Wildlife Service, Personal Communication; Cheri Patterson, State of New Hampshire Fish and Game Department, Personal Communication, 2003). For the bypass channel alternative it was also assigned a value

of 0.80 due to the uncertainties associated with this type of channel (as discussed above for alewives).

Downstream Passage (trr5)- For each of the alternatives, this requisite was assigned the same values as it was for alewife, for the same reasons. These values are: For No Action, 0.25; for Dam Removal, 1.0; for the Denil Fish Ladder, 0.65; and for the Nature-Like Bypass Channel, 0.90.

Spawning Habitat (trr6)- American shad spawn in areas of quiet water, such as broad shallow flats in a river or shallow water ((Smith 1907; Bigelow and Welsh 1925; Hildebrand and Schroeder 1928; Massman 1952; Marcy 1972, from Stier and Crance, 1985). They can spawn over a variety of substrates, but prefer sand and gravel with sufficient water velocity to eliminate silt deposits, and at depths ranging from 1.5 to 40 feet (numerous citations from Stier and Crance). This suggests that the Wiswall Dam impoundment itself may provide some spawning habitat for American shad. Therefore, this requisite was assigned a value of 0.75 for all of the alternatives except Dam Removal, for which it is assigned a value of 0.70 due to the loss of the impoundment, which could act as a spawning area.

Atlantic Salmon- This species has been the subject of a historic restoration effort. As noted in the Environmental Assessment, fry have been stocked upstream of the Macallen Dam, and adults have returned to the fishway.

Upstream Passage (trr7)-This requisite was assigned the same values as for alewife and shad, for each of the alternatives. They are: 0.0, for the No Action; a value of 1.0 for the Dam Removal; a value of 0.8 for the Denil Fish Ladder, and 0.8 for the Nature-Like Bypass Channel.

Downstream Passage (trr8)- This was also assigned the same values as for the other two anadromous species listed above, and for the same reasons. These are: For No Action, 0.25; for Dam Removal, 1.0; for the Denil Fish Ladder, 0.65; and for the Nature-Like Bypass Channel, 0.90.

Spawning Habitat (trr9)-As noted in the Environmental Assessment, it is presumed that Atlantic salmon historically spawned in the Lamprey River. Therefore historic spawning habitat exists in the watershed. Atlantic salmon require cold clear streams with small cobbles/gravel bottoms for construction of spawning redds. Suitable spawning habitat exists in tributaries to the Lamprey River as well as in areas of the River itself. This requisite was therefore assigned a value of 0.60 for the No Action Alternative; a value of 0.70 for the Dam Removal, since the channel in the area of the impoundment itself may provide some additional spawning habitat; a value of 0.60 for the Fish ladder and a value of 0.65 for the Nature-Like Bypass Channel, since the bypass channel itself could provide some spawning habitat for this species.

Wetland Habitat Requisites

General Habitat Requisites for Wetland Avian Species/Waterfowl

As discussed previously, extensive areas of fringing wetlands border the Lamprey River upstream from the Wiswall Dam. In addition, areas of cattail marsh are located on the northern shore near the pumping station. These areas could potentially provide habitat for a number of avian species, which include pied billed grebe, common moorhen, least bittern, King rail, as well as Mallard duck (and presumably Black duck). The set of general habitat requisites (**GRw**) necessary for all of these species include:

- 1) **The percent of emergent and scrub shrub wetland vegetation containing cattail and sedges adjacent to open water (grw_1).** This is defined by the actual area of this type of habitat and its proximity to an area of open water, based upon the assumption that the cover for refuge and nesting habitat is as important as the open water is for feeding habitat. This is also a measure of the location of the wetland in relation to the body of water. Assumptions are that a long narrow edge of this type of habitat is less suitable than a circular or rectangular tract of habitat located near the body of water with its edge extending in the water, or a long narrow strip of water adjacent to a larger area of emergent cattail marsh. Therefore those areas with long narrow edges would be less optimal than those that contain approximately equally sized areas. However, it also may be beneficial for these areas of the emergent cattail habitat to be divided into two or more larger areas surrounded by open water (i.e. islands), since some species nest in smaller areas of cattail marsh surrounded by open water i.e. King Rail and Pied Billed Grebe. The assumption is that the optimum ratio or percentage would be 50:50, with an assumed optimum distribution being arranged with a half of this habitat located on an edge of the water, and half surrounded by water.
- 2) **The percent of open water < 3 feet deep (grw_2).** (This is utilized by dabbling ducks as well as other avian wetland species). This is necessary for dabbling (feeding), in order for the various waterfowl noted above to reach the bottom, which contains food items. In addition, some of the above species feed in areas that are only several inches deep (King Rail). Others nest in these areas.
- 3) **Ratio of open water to emergent vegetation (grw_3)** (50:50 is optimal) (Waterfowl Management Handbook, 1992; Vermont Agency of Natural Resources, 1999). This measures the actual amounts of emergent vegetation in the water itself (i.e. the shallow and/or deeper areas inhabited by aquatic vegetation). It is the measure of the area of the open water itself occupied by emergent vegetation, as compared to the un-vegetated open water. This is generally used by most waterfowl species for most of life stages, i.e. nesting and refuge habitat would be in the emergent vegetation, and feeding habitat would be in or near the open water, or edge areas.

These three variables comprise the general wetland habitat requisites for the Lamprey River upstream from the Wiswall Dam as noted in the general formula on pages 5 and 6

(GRw). They will be discussed in further detail below, and also evaluated as to their degree of change with each of the alternatives to obtain individual values (grw).

Specific Habitat Requisites for Target Species (TRw) (Black Duck) (*Anas rubripes*).

The specific Habitat Requisites for this species include

- 1) **The density of the rooted (including emergent) vegetation present in the open water areas (trw₁).** Assume that a density of 50% is optimal. Denser stands can interfere with swimming, feeding, and can cause entanglement.
- 2) **Percent of backwater supporting insect larvae (trw₂)** (i.e. mosquitoes) and other invertebrates for feeding of young (assume that 50:50 is optimal). It would be measured by the amount of small shallow pools located or interspersed with the emergent wetland vegetation. Newly hatched black duck young feed on mosquito larvae, and other invertebrates (Environment Canada) as well as ducklings of most species. In addition, pre-nesting adults require additional protein in the form of aquatic invertebrates found in shallow diverse wetland communities.
- 3) **Percent of nesting habitat (i.e. scrub shrub/emergent vegetation within 1 mile of water) (trw₃).** This would generally measure other types of habitat present (i.e. scrub shrub) wetland within one mile from the open water, in addition to the existing cattail/sedge habitat. This species can generally nest in sedge, scrub/shrub, or wooded habitats. However in Maine this species preferred sedge shrub marshland when available (Kibbe and Laughlin, 1985). These areas need to be within a reasonable distance from the water to minimize mortality of young during their migration from the nesting areas

Each of these specific habitat requisites (trw) for the target species (i.e. black duck) will be assigned a value for each alternative and incorporated into the general formula noted above, in order to obtain the overall index value for the fish and waterfowl habitat in Lamprey River.

Discussion of General Habitat Requisites for Wetland Avian Species/Waterfowl

1. Percent of Cattail Marsh adjacent to open water:

As noted, the habitat maintained by the Wiswall Dam is characteristic of that which could support several avian wetland/waterfowl species. Generally some of these can inhabit the cattail marsh, such as that which occurs near the pumping station. These could include 1) the **Least Bittern** (*Ixobrychus exilis*); 2) the Pied Billed Grebe (*Podilymbus podiceps*); 3) the King Rail; 4) the Common Moorhen. These are described

below with their habitat requirements. It should be noted that all of these have the requirement of extensive areas of Cattail Marsh adjacent to open water.

The Least Bittern (*Ixobrychus exilis*) is **Restricted to Extensive cattail marshes** (Veit and Petersen, 1993) **for breeding, Cattail and sedge marshes** (Laughlin and Kibbe, 1985). Nests in emergent vegetation usually near open water. It is generally a wader but can also climb about on emergent vegetation so it therefore can nest and forage over water considerably deeper than would be accessible through wading (Laughlin and Kibbe, 1985). Therefore, the assumption is that ideal habitat includes areas of extensive cattail marsh, adjacent to open water.

Pied -billed Grebe (*Podilymbus podiceps*). This species prefers to nest in marshes, lakes, large ponds and other wetlands, which have an abundant **supply of cattails, reeds, and other vegetation, which can provide cover and nesting materials** (Pied-billed Grebe fact sheet). Nests are built with decayed reeds, sedges, grasses, and other vegetation. Nests are located in thick vegetation near to or surrounded by open water, which allows birds to travel to and from the nest underwater and undetected. Breeding territory generally comprises the area within 150 feet of the nest. They feed on aquatic vegetation, seeds, frogs, tadpoles, fish aquatic insects and crayfish (Pied billed Grebe fact sheet, Massachusetts).

King Rail (*Rallus elegans*). This species inhabits large **freshwater and brackish marshes, dominated by cattails, and other emergent vegetation**. They are inclined to wander onto adjacent fields (King Rail fact sheet, Commonwealth of Massachusetts). Usually remain hidden among the dense vegetation. Small strips of freshwater marshland are used as breeding territories. Forage in shallow water 2-3" deep concealed by vegetation. Their diet includes insects, slugs, tadpoles, small frogs, crayfish, grains and seed from aquatic plants. **The nests are made of sedges and grasses in cattails or other dense vegetation.**

Common Moorhen (*Gallinula chloropus*). This species inhabits large **freshwater marshes and ponds with cattails** (*Typha* spp.) and other emergent vegetation. It feeds by wading or diving at the edges of open water. Its food is made up of grass **and sedge seeds and insects** (common moorhen fact sheet, Commonwealth of Massachusetts). **These birds forage on open water** swimming and diving in order to prey on vegetation and aquatic invertebrates, and therefore can often be mistaken for ducks. Nests are built of dead cattails sedges and reeds, and **are located in dense emergent vegetation in water depths of 1-3 feet** (Laughlin and Kibbe, 1985).

In addition, many waterfowl species (i.e. black duck and/or mallard duck) utilize emergent cattail marsh habitat for cover and nesting. American Black Duck (*Anas rubripes*) habitat includes open marshes, to densely wooded swamps (Veit and Petersen, 1993); such as beaver ponds, glacial kettles, surrounded by bog mats, along creeks, and rivers, on lakes in swamps as well as **extensive sedge or cattail marshland**. However in Maine, this species preferred sedge-shrub marshland when available (Kibbe and Laughlin, 1985). It is assumed that the habitat requirements for mallard duck would be

similar, since this species is often found associated with black duck, and is believed to interbreed with it.

For the Lamprey River, it is assumed that the existing proportion of cattail marsh is optimal for the above species.

2. The percent of open water less than 3 feet deep. Shallow water less than 3 feet deep is used by avian wetland and waterfowl species. Dabbling ducks including black duck require areas of open water less than 3 feet deep in order to forage (Fish and Wildlife Service, Habitat Suitability Index Model for Black Duck). In addition the Common moorhen, which occurs in nests in areas of water less than 3 feet deep. (Common Moorhen fact sheet, Commonwealth of Massachusetts).

3. Ratio of open water to emergent vegetation. In addition to the amount of cattail and sedge wetland noted in the first variable, the amount of the open water (either shallow or deep) occupied by emergent vegetation is important. Wetlands most attractive to dabbling ducks contain about a 50:50 ratio of open water to emergent vegetation. Patches of emergent plants, sparse enough to allow a duck to swim through a re more attractive than large blocks of thick, unbroken vegetation (Waterfowl Management Handbook, 1992; Vermont Pond Construction Guidelines, 1999).

Application of Variables to the Lamprey River, Upstream from Wiswall Dam. These requisites with their values and functional grouping are discussed below. Habitat indices were calculated for four alternatives, i.e. 1) No Action, 2) Dam Removal, 3) Construction of a Denil fish ladder, and 4) Construction of a Nature-Like Bypass Channel.

Each of the requisites was assigned a value of 1.0 for every alternative, with the exception of Dam Removal. For this alternative the values will be discussed below.

Wetland General Requisites (GRw).

Emergent Vegetation/Scrub Shrub (grw1) - This was assigned a value of 0.25 for the Dam Removal Alternative, since most of this will be drained, and revert to upland. Therefore it was assigned a value of 0.25 for this alternative.

Percent Open Water Less than 3 feet Deep (grw2)- This was assigned a value of .25 for the Dam Removal Alternative, since most of the shallow inlets and backwaters supported by the water level of the impoundment will be eliminated. However, it is expected that there will be some amount of open water less than 3 feet deep along the margins of the river in the remaining pools.

Percent Vegetated Open Water (grw3)- This was also assigned a value of 0.25 for the same reason as noted above (i.e. drainage of wetlands and remaining vegetated open water in pools).

Specific Habitat Requisites (Black Duck)

These were assigned values of 1 for all alternatives except the Dam Removal Alternative. They are discussed below for that alternative.

The density of the rooted (including emergent) vegetation present in the open water areas (trw₁). - This was assigned a value of 0.30 for the Dam Removal Alternative, since most of the impoundment will drain. However, some of the larger pools left in the river may provide an area for rooted vegetation to establish. Since the deep area of the river (noted in the lacustrine section) may still provide some deeper riverine pools.

Percent of backwater supporting insect larvae (trw₂). - This was assigned a value of 0.25 for the Dam Removal Alternative, since most of the backwater is contained in the adjacent wetlands, which will drain with Dam Removal.

Percent of nesting habitat (i.e. scrub shrub/emergent vegetation within 1 mile of water) (trw₃). - This was assigned a value of 0.75 for the Dam Removal Alternative since it is presumed that there will still be some areas of vegetated scrub shrub suitable for nesting within 1 mile of the impoundment, even with the impoundment gone.

Calculation of Habitat Units

Habitat Units for each of the Lamprey River fish passage alternatives were calculated according to the formula noted above, where the Indices obtained for the lacustrine (i.e. fisheries) habitat, riverine (i.e. anadromous fish) habitat and wetland (i.e. waterfowl) habitat were multiplied by the total acres of the respective habitat types that will become available with each alternative. These calculations of individual Habitat Indices (HI) are presented in the attached spreadsheet with the respective Habitat Units (HU) (See Attachment 2). The acreages used to obtain the habitat units are presented below. The methods for calculating these acreages are presented in Attachment 1.

Alternative 1- No Action

Lacustrine Habitat-The Wiswall Dam creates an impoundment that extends approximately 8000 feet upstream on the Lamprey River. By using CAD aerial calculations the total area is calculated to be approximately 25.5 acres (See Attachment 2).

Riverine Habitat-There are 43 river-miles above the Wiswall dam that are not obstructed by other dams. This includes the impounded reach behind Wiswall Dam and several miles of the Lamprey River as well as its tributaries. By measuring average

widths (based upon topographic maps) for tributaries and river reaches, there are approximately 217 acres of wetted surface that would become accessible to anadromous fish if the dam were removed. However in its existing condition, the dam supports the impoundment (an additional 6.5 acres) as well as the wetlands (discussed below, at 9.5 acres) for a total of 233 acres of water surface. Although with the existing dam in place (without fish passage), this habitat is inaccessible to anadromous fish, it can still serve as nursery and/or spawning habitat for fish that have been artificially transported over the dam.

Wetland/Waterfowl Habitat-There are approximately 9.5 acres of wetlands adjacent to the impoundment, supported by its existing water level (which is the spillway elevation) (See Attachment 1). In addition, it is assumed that any waterfowl that occupy these wetlands also utilize the open water of the Wiswall Dam impoundment. Therefore, the 25.5 acres of lacustrine habitat is included in the total area of this habitat type, for a total of 35 acres.

Alternative 2-Dam Removal

Lacustrine Habitat-In this alternative, the impoundment would be drained (as well as the adjacent wetland). The habitat would revert to the historical riverine habitat upstream from the dam. The loss of the impoundment would eliminate approximately 6.5 acres of water surface as measured from the Wiswall Dam upstream for a distance of 8000 feet. The former impoundment would be replaced by free flowing river, for a reduction from the former 25.5 acres to 19 acres. The remaining 6.5 acres of lost water surface would revert to upland riparian habitat, and would not be counted as aquatic habitat acreage.

Riverine Habitat-In addition to the loss of the 6.5 acres, the 9.5 acres of the adjacent wetland (previously included with former riverine habitat) would be lost, for a total reduction of 16 acres of water surface. Therefore the 233 acres of water surface included as the total riverine habitat upstream from the dam would be reduced to 217 acres; with as noted above, the former 16 acres of wetlands would revert to upland habitat, and would not be counted as aquatic habitat acreage.

Wetland/Waterfowl Habitat-With Dam Removal, the 9.5 acres of wetland habitat adjacent to the impoundment, and supported by it would drain. In addition, as discussed above, the impoundment would be eliminated and replaced by free flowing river for an additional loss of 6.5 acres of water surface. Therefore, for the Dam Removal Alternative, the wetland/waterfowl habitat would be reduced by 16 acres, changing from 35 acres to 19 acres. The 16 acres of drained wetlands would revert to upland habitat, and would not be counted as aquatic habitat acreage.

Alternative 3-Denil Fish Ladder

Lacustrine Habitat-Since the impoundment will remain in place in this alternative, there will be 25.5 acres of lacustrine habitat, the same as for the No Action Alternative.

Riverine Habitat-For this alternative, the impoundment upstream from the dam as well as the wetlands will remain intact. Therefore the acres of water surface will remain at 233 (as in the No Action Alternative).

Wetlands/Waterfowl-Since the impoundment will remain in this alternative, the 35 acres of wetland/waterfowl habitat artificially created by it will remain unchanged.

Alternative 4-Nature-Like Bypass Channel

Lacustrine Habitat-This will remain at 25.5 acres since the impoundment will be maintained in this alternative.

Riverine Habitat- The 1000-foot nature-like bypass channel will add approximately 1 acre of riverine habitat, bringing the total to 234 acres for this alternative.

Waterfowl/Wetland Habitat- This will remain at 35 acres for this alternative, due to the maintenance of the existing water levels from the Wiswall Dam.

Habitat Units

Using the acreages calculated above for each habitat type, habitat units were calculated by multiplying them by the respective Habitat Suitability Index (HI) obtained for each alternative. The total habitat units for all habitat types for each alternative were obtained by multiplying the lacustrine and wetland waterfowl acreages (for each alternative) by 0.25, and adding these to the riverine habitat units. This was done in order to emphasize the federal significance of anadromous fish restoration relative to other habitat functions in this project. These weighted habitat units are presented below. The unweighted totals are presented in the attached spreadsheet.

Alternative 1, No Action

Lacustrine HU's = 21.97.

Riverine HU's = 90.78

Wetland/Waterfowl HU's = 34.98

Total Habitat Units = $((21.97+34.98) \times 0.25) + 90.7844 = \mathbf{105.02}$

Alternative 2, Dam Removal

Lacustrine HU's = 8.59.

Riverine HU's = 201.58

Wetland/Waterfowl HU's = 6.25

$$\text{Total Habitat Units} = ((8.59+6.25) \times 0.25) + 201.58 = \mathbf{205.29}$$

Alternative 3, Denil Fish Ladder

Lacustrine HU's = 22.97.

Riverine HU's = 152.06

Wetland/Waterfowl HU's = 34.98

$$\text{Total Habitat Units} = ((22.97+34.98) \times 0.25) + 152.06 = \mathbf{166.55}$$

Alternative 4, Nature-Like Bypass Channel

Lacustrine HU's = 23.31

Riverine HU's = 175.60

Wetland/Waterfowl HU's = 34.98

$$\text{Total Habitat Units} = ((23.31+34.98) \times 0.25) + 175.60 = \mathbf{190.17}$$

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Attachment 1

Calculation of Aquatic Habitat Acreages

Total river miles available upstream of Wiswall Dam for anadromous fish = 43 miles
(from Lamprey River Report)

Impoundment reach length = 8,200 feet = 1.55 miles

Impoundment acreage full (mean annual discharge) = 25.5 acres from CAD using topography supplied by Eastern Topographics from aerial photo taken 09 May 86 and contracted bathymetric survey performed for Corps in April 2002

Impoundment acreage drained (no dam) at mean annual discharge = 19 acres determined using survey data and mapping as above and HEC RAS analysis

Wetlands connected to impoundment behind dam = 9.5 acres from CAD, using elevation at mean annual discharge, and verified by comparing to mapping performed by Eastern Topographics from aerial photo taken 09 May 86 and field verified by Corps in Nov 2001 and May 2002.

Remaining river upstream of impounded area = 43 miles - 1.55 miles = 41.45 miles

Total acreage of this 41.45-mile reach:

Length of reach	Range of width	Mean Width	Acreage of reach
4.45 miles	60-120 feet	90 feet	48 acres
20 miles	30-60 feet	45 feet	109 acres
17 miles	10-30 feet	20 feet	41 acres
Total (41.45 mile reach above impoundment reach)			198 acres

Bypass channel acreage = 1 acre based on CAD design

Riverine area calculations:

Riverine area for the study is the riverine area above the dam that could be opened to anadromous fish plus any added riverine habitat from channel construction.

No Action (Without Project) riverine acreage = impoundment area full (25.5 acres) + connected wetlands (9.5 acres) + river acreage above impoundment (198 acres) = **233 acres**)

Dam Removal riverine acreage = impoundment area drained (18.9 acres) + river acreage above impoundment (198 acres) = 221.9 acres (rounded to **217 acres**)

Denil Ladder riverine acreage = impoundment area full (25.5 acres) + connected wetlands (9.5 acres) + river acreage above impoundment (198 acres) = **233 acres**)

Bypass Channel riverine acreage = impoundment area full (25.5 acres) + connected wetlands (9.5 acres) + river acreage above impoundment (198 acres) + bypass channel acreage (1 acre) = **234 acres**)

Lacustrine area calculations:

Lacustrine habitat is considered the area that functions as open water lacustrine habitat in the impoundment reach (8,200-foot long reach upstream of Wiswall Dam).

No Action lacustrine acreage = impoundment area full (**25.5 acres**)

Dam Removal lacustrine acreage = impoundment area drained (**19 acres**)

Denil ladder lacustrine acreage = impoundment area full (**25.5 acres**)

Bypass channel lacustrine acreage = impoundment area full (**25.5 acres**)

Waterfowl Habitat area calculations:

Waterfowl habitat is considered the open water and wetlands adjacent to the river in the 8,200-foot reach above Wiswall Dam.

No Action waterfowl habitat acreage = impoundment area full (25.5 acres) + connected wetlands (9.5 acres) = **35 acres**).

Dam Removal waterfowl habitat acreage = impoundment area drained (**19 acres**)

Denil ladder waterfowl habitat acreage = impoundment area full (25.5 acres) + connected wetlands (9.5 acres) = **35 acres**).

Bypass channel waterfowl habitat acreage = impoundment area full (25.5 acres) + connected wetlands (9.5 acres) = **35 acres**).

Attachment 2
(See Attached Spreadsheet)

Wiswall Dam Fish Passage - Habitat Units of Optimal Restored Riverine Habitat Available Under Various Project Conditions									
Alternative 1: No Action									
	Value	Weight Multiplier	Adjusted Value	Total Score	Total Possible Score	Habitat Index	Habitat Acres	Habitat Units	
General Habitat Requisites (Lacustrine)									
DO	0.75	1	0.75			0.74			
Turbidity	1.00	1	1.00						
Temperature	0.75	1	0.75						
Benthic Inverts	0.75	1	0.75						
Cover	0.80	1	0.80						
Forage	0.50	1	0.50						
			0.76	0.74	1				
				0.74	1	0.74			
Specific Habitat Requisites									
Warmwater Species									
Largemouth Bass									
Littoral Habitat	1.00	0.333	0.33						
Spawning Substrate	1.00	0.333	0.33						
Deepwater Habitat	1.00	0.333	0.33						
				1.00	0.999	1.00			
Total HI for Lacustrine Fisheries Component						0.86	25.50	21.97	
General Habitat Requisites (Riverine)									
DO	0.50	1	0.50						
Turbidity	1.00	1	1.00						
Temperature	0.50	1	0.50						
Benthic Inverts	0.75	1	0.75						
Cover	0.25	1	0.25						
Forage	0.50	1	0.50	0.53					
Flow	0.25	1	0.25	0.48					
			0.54	0.48	1	0.48			
Specific Habitat Requisites									
Anadromous Species									
Alewife									
Upstream Passage	0.00	0.111	0.00						
Downstream Passage	0.25	0.111	0.03						
Spawning Habitat	0.75	0.111	0.08						
	0.00			0.11	0.333	0.11			
American Shad									
Upstream Passage	0.00	0.111	0.00						
Downstream Passage	0.25	0.111	0.03	0.11	0.333	0.11			
Spawning Habitat	0.75	0.111	0.08						
Atlantic Salmon									
Upstream Passage	0.00	0.111	0.00						
Downstream Passage	0.25	0.111	0.03						
Spawning Habitat	0.60	0.111	0.07	0.09	0.333	0.09			
					0.999	0.32			
Total Habitat Index for Riverine Component						0.39	233.00	90.78	
Wetland/Waterfowl									
General Requisites									
Emergent Vegetation/scrub shrub	1.00	1	1.00						
Percent Open water < 3 feet deep	1.00	1	1.00						
Percent vegetated open water	1.00	1	1.00						
				1.00	1	1.00			
Specific Habitat Requisites									
Black Duck									
Open Water:Emergent Vegetation, Density	1.00	0.333	0.33						
Percent Backwater	1.00	0.333	0.33						
% Emergent/scrub shrub Within 1 mile of pond	1.00	0.333	0.33	1.00	0.999	1.00			
Total Habitat Index for Waterfowl Component						1.00	35.00	34.98	
Total Habitat Units (Habitat Index X Acres)									147.74

Wiswall Dam Fish Passage - Habitat Units of Optimal Restored Riverine Habitat Available Under Various Project Conditions								
Alternative 2: Dam Removal								
	Value	Weight Multiplier	Adjusted Value	Total Score	Total Possible Score	Habitat Index	Habitat Acres	Habitat Units
General Habitat Requisites (Lacustrine):								
DO	1.00	1	1.00			0.61		
Turbidity	1.00	1	1.00					
Temperature	0.50	1	0.50					
Benthic Inverts	0.50	1	0.50					
Cover	0.25	1	0.25					
Forage	0.85	1	0.85					
			0.68	0.61	1			
				0.61	1	0.61		
Specific Habitat Requisites								
Warmwater Species								
Largemouth Bass								
Littoral Habitat	0.25	0.333	0.08					
Spawning Substrate	0.25	0.333	0.08					
Deepwater Habitat	0.50	0.333	0.17					
				0.33	0.999	0.33		
Total HI for Lacustrine Fisheries Component						0.45	19.00	8.59
General Habitat Requisites (Riverine):								
DO	1.00	1	1.00					
Turbidity	1.00	1	1.00					
Temperature	0.75	1	0.75					
Benthic Inverts	1.00	1	1.00					
Cover	1.00	1	1.00					
Forage	1.00	1	1.00	0.95				
Flow	1.00	1	1.00	0.96				
			0.96	0.96	1	0.96		
Specific Habitat Requisites								
Anadromous Species								
Alewife								
Upstream Passage	1.00	0.111	0.11					
Downstream Passage	1.00	0.111	0.11					
Spawning Habitat	0.70	0.111	0.08					
				0.30	0.333	0.30		
American Shad								
Upstream Passage	1.00	0.111	0.11					
Downstream Passage	1.00	0.111	0.11	0.30	0.333	0.30		
Spawning Habitat	0.70	0.111	0.08					
Atlantic Salmon								
Upstream Passage	1.00	0.111	0.11					
Downstream Passage	1.00	0.111	0.11					
Spawning Habitat	0.70	0.111	0.08	0.30	0.333	0.30		
					0.999	0.90		
Total Habitat Index for Riverine Component						0.93	217.00	201.58
Wetland Restoration								
General Requisites								
Emergent Vegetation/scrub shrub	0.25	1	0.25					
Percent Open water < 3 feet deep	0.25	1	0.25					
Percent vegetated open water	0.25	1	0.25					
				0.25	1	0.25		
Specific Habitat Requisites								
Black Duck	0.00							
Open Water:Emergent Vegetation, Density	0.30	0.333	0.10					
Percent Backwater	0.25	0.333	0.08					
% Emergent/scrub shrub Within 1 mile of pond	0.75	0.333	0.25	0.43	0.999	0.43		
Total Habitat Index for Waterfowl component						0.33	19.00	6.25
Total Habitat Units (Habitat Index X Acres)								216.41

Wiswall Dam Fish Passage - Habitat Units of Optimal Restored Riverine Habitat								
Available Under Various Project Conditions								
Alternative 3: Construction of a Fish Ladder								
	Value	Weight Multiplier	Adjusted Value	Total Score	Total Possible Score	Habitat Index (HI)	Habitat Acres	Habitat Units (HI X Acres)
General Habitat Requisites (Lacustrine)								
DO	0.75	1	0.75			0.81		
Turbidity	1.00	1	1.00					
Temperature	0.75	1	0.75					
Benthic Inverts	0.75	1	0.75					
Cover	0.80	1	0.80					
Forage	0.85	1	0.85					
			0.82	0.81	1			
				0.81	1	0.81		
Specific Habitat Requisites								
Warmwater Species								
Largemouth Bass								
Littoral Habitat	1.00	0.333	0.33					
Spawning Substrate	1.00	0.333	0.33					
Deepwater Habitat	1.00	0.333	0.33					
				1.00	0.999	1.00		
Total Habitat Index for Lacustrine Fisheries Component						0.90	25.50	22.97
General Habitat Requisites (Riverine)								
DO	0.50	1	0.50					
Turbidity	1.00	1	1.00					
Temperature	0.50	1	0.50					
Benthic Inverts	0.75	1	0.75					
Cover	0.75	1	0.75					
Forage	0.75	1	0.75	0.69				
Flow	0.25	1	0.25	0.59				
			0.67	0.59	1	0.59		
Specific Habitat Requisites								
Anadromous Species								
Alewife								
Upstream Passage	0.80	0.111	0.09					
Downstream Passage	0.65	0.111	0.07					
Spawning Habitat	0.75	0.111	0.08					
				0.24	0.333	0.24		
American Shad								
Upstream Passage	0.80	0.111	0.09					
Downstream Passage	0.65	0.111	0.07	0.24	0.333	0.24		
Spawning Habitat	0.75	0.111	0.08					
Atlantic Salmon								
Upstream Passage	0.80	0.111	0.09					
Downstream Passage	0.65	0.111	0.07					
Spawning Habitat	0.60	0.111	0.07	0.23	0.333	0.23		
					0.999	0.72		
Total Habitat Index for Riverine Component						0.65	233.00	152.06
Wetland Restoration								
General Requisites								
Emergent Vegetation/scrub shrub	1.00	1	1.00					
Percent Open water < 3 feet deep	1.00	1	1.00					
Percent vegetated open water	1.00	1	1.00					
				1.00	1	1.00		
Specific Habitat Requisites								
Black Duck								
Open Water:Emergent Vegetation, Density	1.00	0.333	0.33					
Percent Backwater	1.00	0.333	0.33					
% Emergent/scrub shrub Within 1 mile of pond	1.00	0.333	0.33	1.00	0.999	1.00		
Total Habitat Index for Waterfowl component						1.00	35.00	34.98
Total Habitat Units (Habitat Index X Acres)								210.01

Wiswall Dam Fish Passage - Habitat Units of Optimal Restored Riverine Habitat Available Under Various Project Conditions									
Alternative 4: Construction of Nature-Like Bypass Channel									
	Value	Weight Multiplier	Adjusted Value	Total Score	Total Possible Score	Habitat Index	Habitat Acres	Habitat Units	
General Habitat Requisites (Lacustrine)									
DO	0.75	1	0.75			0.84			
Turbidity	1.00	1	1.00						
Temperature	0.75	1	0.75						
Benthic Inverts	0.80	1	0.80						
Cover	0.80	1	0.80						
Forage	0.95	1	0.95						
			0.84	0.84	1				
				0.84	1	0.84			
Specific Habitat Requisites									
Warmwater Species									
Largemouth Bass									
Littoral Habitat	1.00	0.333	0.33						
Spawning Substrate	1.00	0.333	0.33						
Deepwater Habitat	1.00	0.333	0.33						
				1.00	0.999	1.00			
Total HI for Lacustrine Fisheries Component						0.91	25.50	23.31	
General Habitat Requisites (Riverine)									
DO	0.50	1	0.50						
Turbidity	1.00	1	1.00						
Temperature	0.65	1	0.65						
Benthic Inverts	0.85	1	0.85						
Cover	0.70	1	0.70						
Forage	0.85	1	0.85	0.74					
Flow	0.50	1	0.50	0.70					
			0.76	0.70	1	0.70			
Specific Habitat Requisites									
Anadromous Species									
Alewife									
Upstream Passage	0.80	0.111	0.09						
Downstream Passage	0.90	0.111	0.10						
Spawning Habitat	0.75	0.111	0.08						
				0.27	0.333	0.27			
American Shad									
Upstream Passage	0.80	0.111	0.09						
Downstream Passage	0.90	0.111	0.10	0.27	0.333	0.27			
Spawning Habitat	0.75	0.111	0.08						
Atlantic Salmon									
Upstream Passage	0.80	0.111	0.09						
Downstream Passage	0.90	0.111	0.10						
Spawning Habitat	0.65	0.111	0.07	0.26	0.333	0.26			
					0.999	0.80			
Total Habitat Index for Riverine Component						0.75	234.00	175.60	
Wetland Restoration									
General Requisites									
Emergent Vegetation/scrub shrub	1.00	1	1.00						
Percent Open water < 3 feet deep	1.00	1	1.00						
Percent vegetated open water	1.00	1	1.00						
				1.00	1	1.00			
Specific Habitat Requisites									
Black Duck									
Open Water:Emergent Vegetation, Density	1.00	0.333	0.33						
Percent Backwater	1.00	0.333	0.33						
% Emergent/scrub shrub Within 1 mile of pond	1.00	0.333	0.33	1.00	0.999	1.00			
Total Habitat Index for Waterfowl component						1.00	35.00	34.89	
Total Habitat Units (Habitat Index X Acres)									233.89

Wiswall Dam Fish Passage - Habitat Units of Optimal Restored Riverine									
Habitat Available Under Various Project Conditions									
Variables to be applied to Alternatives									
General Habitat Requisites (Lacustrine)	No Action	Dam Removal	Denil Fish Ladder	Nature-Like Bypass					
DO	0.75	1.00	0.75	0.75					
Turbidity	1.00	1.00	1.00	1.00					
Temperature	0.75	0.50	0.75	0.75					
Benthic Inverts	0.75	0.50	0.75	0.80					
Cover	0.80	0.25	0.80	0.80					
Forage	0.50	0.85	0.85	0.95					
	0.76	0.68	0.82	0.84					
Specific Habitat Requisites									
Warmwater Species									
Largemouth Bass									
Littoral Habitat	1.00	0.25	1.00	1.00					
Spawning Substrate	1.00	0.25	1.00	1.00					
Deepwater Habitat	1.00	0.50	1.00	1.00					
Total HI for Lacustrine Fisheries Component									
General Habitat Requisites (Riverine)									
DO	0.50	1.00	0.50	0.50					
Turbidity	1.00	1.00	1.00	1.00					
Temperature	0.50	0.75	0.50	0.65					
Benthic Inverts	0.75	1.00	0.75	0.85					
Cover	0.25	1.00	0.75	0.70					
Forage	0.50	1.00	0.75	0.85					
Flow	0.25	1.00	0.25	0.50					
Specific Habitat Requisites									
Anadromous Species									
Alewife									
Upstream Passage	0.00	1.00	0.80	0.80					
Downstream Passage	0.25	1.00	0.65	0.90					
Spawning Habitat	0.75	0.70	0.75	0.75					
American Shad									
Upstream Passage	0.00	1.00	0.80	0.80					
Downstream Passage	0.25	1.00	0.65	0.90					
Spawning Habitat	0.75	0.70	0.75	0.75					
Atlantic Salmon									
Upstream Passage	0.00	1.00	0.80	0.80					
Downstream Passage	0.25	1.00	0.65	0.90					
Spawning Habitat	0.60	0.70	0.60	0.65					
Total Habitat Index for Riverine Component									
Wetland Restoration									
General Requisites									
Emergent Vegetation/scrub shrub	1.00	0.25	1.00	1.00					
Percent Open water < 3 feet deep	1.00	0.25	1.00	1.00					
Percent vegetated open water	1.00	0.25	1.00	1.00					
Specific Habitat Requisites									
Black Duck									
Open Water:Emergent Vegetation, Density	1.00	0.30	1.00	1.00					
Percent Backwater	1.00	0.25	1.00	1.00					
% Emergent/scrub shrub Within 1 mile of port	1.00	0.75	1.00	1.00					
Total Habitat Index for Waterfowl component									
	0.00	0.00	0.00	0.00					

Attachment 3

Incremental Cost Analysis

Incremental Cost Curve

In this section, the costs of the alternative restoration plans are compared with the environmental benefits, within the framework of an incremental cost analysis, to display the most cost effective alternatives. An incremental cost analysis examines how the costs of additional units of environmental output increase as the level of environmental output increases. For this analysis, the environmental outputs are measured in habitat units. The analysis is in accordance with IWR Report 95-R-1, Evaluation of Environmental Investments Procedures Manual-Interim: Cost Effectiveness and Incremental Cost Analyses, May 1995; and ER 1105-2-100, Planning Guidance Notebook, Section 3-5, Ecosystem Restoration, April 2000. The program IWR-PLAN, developed for the Institute for Water Resources (IWR), was used to conduct the analysis.

An incremental cost curve can be identified by displaying cost effective solutions. Cost effective solutions are those increments that result in same output, or number of habitat units, for the least cost. An increment is cost effective if there are no others that cost less and provide the same, or more, habitat units. Alternatively, for a given increment cost, there will be no other increments that provide more habitat units.

Management plans to improve environmental conditions in the Lamprey River include a fish ladder, fish passage and Dam Removal. Project description, project cost, and the number of habitat units created by each plan are shown in Table 1. Costs are discounted at an interest rate of 5 7/8 %. This interest rate, as specified in the Federal Register, is to be used by Federal agencies in the formulation and evaluation of water and land resource plans for the period October 1, 2002 to September 30, 2003. The project economic life is considered to be 50 years.

Alternative 1 is the No Action Alternative. Alternative 2 provides for dam removal. Alternative 3 provides for a Denil fish ladder. Alternative 4 provides for a nature-like bypass. These alternatives are shown in Table 1.

Table 1. Plan Increments Wiswall Dam, Durham, New Hampshire				
Alternative	Description	Project Cost	HU	Increase in HU over Without Project
1	Without Project (No Action)	\$0	105.02	\$0
2	Dam Removal	\$3,426.7	205.29	100.27
3	Denil Fish Ladder	\$982.2	166.55	61.53
4	Nature-Like Bypass	\$890.8	190.17	85.15

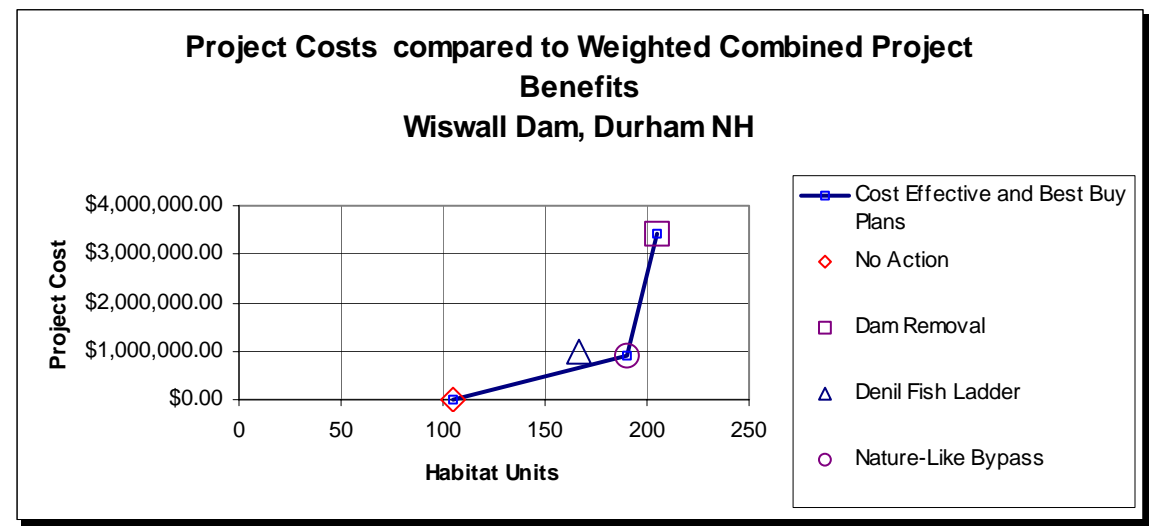
Project cost derivation is shown in Table 2. This cost includes engineering and design (E&D) and Supervisory and Administration (S&A). However, it does not include cost escalation that is included in the financial cost estimate. Preliminary Design and Analysis (PDA) cost is added to construction cost to derive total first cost. Interest during construction (IDC) is then calculated assuming a construction period of 12 months for each alternative. This is an economic cost and not a financial cost. It needs to be estimated for purposes of project justification, however it is not a financial cost that will need to be cost shared. Essentially, IDC represents the opportunity cost of funds tied up in investments, before these investments begin to yield benefit. Once project benefit starts IDC cost stops.

Combining total first cost and IDC results in investment cost. Annual operation and maintenance (O & M) and monitoring costs are then added to investment cost to arrive at total project cost. O & M costs shown in Table 2 are a discounted sum of \$2,000 annually over the 50-year project life. O & M is discounted over 50 years using the discount factor of one per period at an interest rate of 5 7/8 %. Annual monitoring cost is \$1,700 resulting in a discounted sum of \$7,000 over the first five years of project life.

Table 2. Project Cost Wiswall Dam, Durham, New Hampshire (\$000)								
Alter- native	First Project	Other	Total First	Interest During Constr- uction	Invest- ment	O&M	Monit- oring	Total Economic Cost of Project
1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	3,008.6	320.0	3,328.6	91.1	3,419.7	0.0	7.0	3,426.7
3	598.0	320.0	918.0	25.1	943.1	32.1	7.0	982.2
4	509.0	320.0	829.0	22.7	851.7	32.1	7.0	890.8

Figure 1 shows a graphical representation of project costs compared to habitat unit outputs for the four alternatives. It also graphically depicts those plans that are cost effective and best buy plans. All plans except Alternative 3 are cost effective. Alternative 3 provides fewer habitat units than Alternative 4, but at a higher cost. Thus, Alternative 3 is not a cost effective plan. In Figure 1, cost effective plans are arrayed along the horizontal axis by increasing number of habitat units with corresponding project cost shown on the vertical axis. All cost effective plans are also best buy plans.

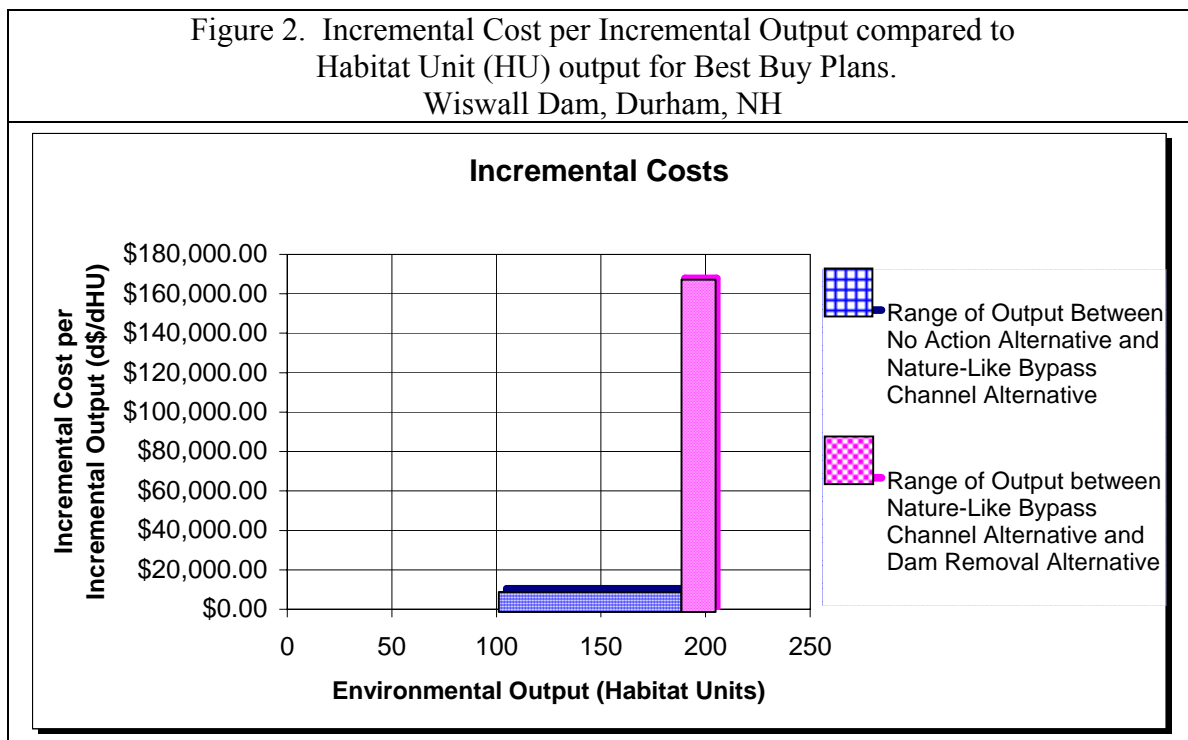
Figure 1. Total project costs are compared to weighted combined project benefits. The benefits depicted are the riverine habitat units added to 25% of the values of the lacustrine and wetland/waterfowl habitat units. Cost Effective and Best Buy Plans are also depicted.



Incremental costs and incremental benefits of each best buy plan are shown in Table 3. Also shown is the incremental cost per output. Incremental costs and incremental outputs are the changes in cost and output when the cost and output of each successive plan in terms of increasing output are compared. Incremental cost per output is the change in cost, or incremental cost divided by the change in output, or incremental output when proceeding to plans with higher output.

Table 3. Incremental Cost Curve and Best Buy Plans Wiswall Dam, Durham, NH							
Plan	Description	Habitat Units (HU)	Cost (\$000)	Average Cost (\$000/HU)	Incremental Cost (\$000)	Incremental Output (HU)	Incremental Cost Per Incremental Output (\$000/HU)
1	Without Project	105.02	0.0	0.0	0.0	0.0	Not applicable
4	Nature-Like Bypass	190.17	890.8	4.7	890.8	85.2	10.5
2	Dam Removal	205.29	3,426.7	16.7	2,535.9	15.1	167.9

A graph showing the relationship between the incremental cost per output and the project cost (shaded columns in Table 3) is referred to as the incremental cost curve. The incremental cost curve is represented in Figure 2 as upward trending bar heights depicting the incremental costs per output compared to habitat unit outputs that can be provided by the best buy plans.



As in Figure 1, the horizontal axis represents habitat units created by each project. However, the vertical axis represents the incremental cost per incremental output as output increases with project size. Best buy plans are a subset of cost effective plans.

For each best buy plan there are no other plans that will give the same level of output at a lower incremental cost. There are three cost effective plans that are also best buy plans.

In the incremental cost curve shown above in Table 3 (shaded columns), and in Figure 2, incremental cost per unit increases with output, or habitat units. Development of the incremental cost curve facilitates the selection of the best alternative. The question that is asked at each increment is: is the additional gain in environmental benefit worth the additional cost? The first increment beyond the without project condition is Alternative 4, that has a total output of 190.17 HU and an incremental cost of \$10,461 per HU. This increment would consist of constructing a nature-like bypass channel. The second and final increment is Alternative 2 that has a total output of 205.29 HU and an incremental cost of \$167,746 per HU. This increment would consist of removing the dam.